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THE BEHAVIOR AND CONTROL OF UNDERSTORY HARDWOODS IN LOBLOLLY PINE STANDS

by

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FOREWORD

If we are going to grow full crops of pine over much of our loblolly pine region, we must be prepared to take adequate cultural measures. The determination of what measures are necessary and where and how to apply them is a function of forest research.

Late in 1946 the Southeastern Forest Experiment Station set up a comprehensive program of research in the behavior and control of understory hardwoods in loblolly pine stands. These investigations are largely centered at the Central Coastal Plain Branch Station at Charleston, S. C., with supplemental work at the North Coastal Plain Branch Station at Franklin, Virginia. Replications of some studies are installed at the West Virginia Experimental Forest near Georgetown, S. C., in cooperation with the West Virginia Pulp and Paper Company.

This technical note reports the results of two years of investigation. It discusses the problem, summarizes our present knowledge, and offers suggested practices. We are aware that few of the statements contained herein are incontrovertible. Most are based on interim observations which may or may not be verified upon conclusion of the investigations. But the demand for information is persistent. We therefore issue this preliminary report.

THE BEHAVIOR AND CONTROL OF UNDERSTORY HARDWOODS IN LOBLOLLY PINE STANDS

A PRELIMINARY REPORT

by

L. E. Chaiken, Silviculturist[1/]

INTRODUCTION

Ecologically the forests of pure or nearly pure southern pine that range so extensively along the central and southern Atlantic coastal region are sub-climax types. Thus the natural tendency is for our pine forests to be replaced eventually by the climax hardwood species: maple, beech, oaks, and hickories.

A number of observers have reported and commented on the changing character of our pine forests. Heyward's studies in 1939 (5) supported the prediction made 50 years previously by Long (8) that in the absence of repeated fires, hardwoods will gradually replace pine. Wells (10) in 1928 stressed the ecologically transient role of loblolly pine and pointed out the succession to hardwoods. Chapman (3) and Barrett and Downs (1), among others, have noted the trend toward hardwoods in the absence of fire. To those who were acquainted with the region prior to organized fire protection, the encroachment of hardwoods in pine stands is quite apparent.

It seems evident now that man's early activity on the coastal plain, such as uncontrolled burning and clearing for agriculture and grazing, helped to perpetuate pure pine. By contrast, his later activity--the logging of pine and exclusion of fire--is assisting the hardwoods,

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1/ The author wishes to acknowledge assistance given him in this study by the following present or former members of the staff of the Central Coastal Plain Branch Station, Charleston, S. C.: Thomas Lotti, K. F. Wenger, S. H. Buehling, D. A. Pomerening, W. P. LeGrande, Jr., and G. P. Jarrett.

reducing pine, and speeding the already strong, natural forest succession tendency toward climax hardwoods.

How does this happen? For one thing, the agriculture of the region is now stabilized, and there are no new large areas reverting to pine forests. Uncontrolled fires have been virtually excluded, thereby removing the greatest influence in keeping hardwoods subordinate. Since these hardwoods are tolerant, their movement to dominate stand positions is a matter of time. Since timber use of the region favors pine, the movement is accelerated. And since loblolly pine is intolerant in its light requirements, it cannot reproduce adequately under a hardwood canopy. There are a number of other factors encouraging the conversion to hardwoods, but the net result is: more hardwoods for the future. On the coastal plain of Virginia and the Carolinas the evidence in the form of dense hardwood understories on former loblolly pine sites is so conspicuous that it cannot be ignored.

No unanimity exists among foresters as to whether we should permit the successional trend to continue and grow less pine and more hardwood, or whether we should arrest the trend and manage our timber lands to grow as much pine as we can with reasonable expenditure. We might therefore briefly review the main points at issue.

First, there seems to be a certain vagueness as to where the problem exists. Although no one is yet in position to classify specifically all the sites that are better suited to pine than hardwood, the consensus of opinion is to let the hardwoods grow on moist bottomland and terraces, where hardwoods develop well and are frequently of high quality. It is on the drier sites that the aggressiveness of hardwoods gives us concern.

Second, there is the feeling that we can and should grow hardwoods along with pine. But those hardwoods now invading pine stands are frequently of low valued species and almost always of poor form. There is no doubt that by intensive management we can favor hardwoods of better species, form, and growth rate--much as we improve values in pine stands. It is doubtful, however, whether our present soils can be sufficiently improved within a reasonably short time to grow such high valued hardwoods as black walnut, yellow-poplar, white oak, and the better red oaks. These species are

exacting in their soil requirements. It seems, then, that until we can grow high quality hardwoods, we must recognize that volume and value yields will be less in hardwood or pine-hardwood stands than in pure pine stands.

Third, there is the belief that industry will utilize hardwoods to a greater extent so that our presently "worthless" hardwoods are potentially valuable. We will probably learn to use hardwoods in new ways and in greater quantity. Yet when one considers such possible uses in relation to potential supplies, the large scale expansion of hardwood utilization seems limited. For example, the production of hardwood dissolving pulps for the manufacture of rayon, cellophane, and associated products is growing, but only four percent of the total pulpwood consumption is for dissolving pulps. Even if this use could be doubled or tripled, its effect on hardwood consumption in terms of potential supplies is obviously minor. We must plan to get along with more hardwood in the future and attempt to develop means of expanding utilization, yet this will not solve the problem if hardwoods continue to take over substantial acreages of former pine sites. Foresters must face the fact that substantial conversion to hardwoods and resulting changes in the character of our forest industries will take place only at great expense in terms of plant changes and depreciation as well as in smaller supplies of an inherently more useful material.

Fourth, there is precedent for the argument that the continuous cropping of pine may deteriorate the site and result in diminishing timber yields. Nearly 100 years ago European foresters recognized the dangers of growing successive stands of pure conifers and have turned to mixed species. In northeast United States pine-hardwoods are favored over pure white pine. There is yet no evidence that successive stands of pure pine will cause soil deterioration in the South (6). Many present stands in the region are of site index 90 to 110 feet after at least several generations of pine and of repeated fire. What might the site index be without the pine and without fire?

THE PROBLEM

There are few places in coastal Virginia and the Carolinas that do not show some evidence of the successional trend toward hardwoods. The low vegetation in pine areas is quite closely associated with the length of time since fire exclusion, and gives some clue as to what the condition and composition of succeeding stands might be. The effect of fire in the understory is shown by a comparison of the burned and unburned stands in figures 1 and 2. Soil and other conditions of site, recency of cultivation, availability of seed, treatment of past and present stands, all

Figure 1.--A 40-year-old loblolly pine stand repeatedly burned. The ground cover is mostly grasses and herbaceous material, with a scattering of low hardwood sprouts. This condition was general throughout the loblolly pine region prior to fire protection.

profoundly affect the successional trend. Thus, there are great variations. There are areas where pine might succeed pine quite adequately; elsewhere, it seems certain that pine will form only a minor part of the succeeding stands.

On the moister sites, excluding the stream bottoms, sweetgum (Liquidambar styraciflua) is by far the major understory tree species. Others are blackgum (Nyssa sylvatica), southern red oak (Quercus falcata), water oak (Q. nigra), willow oak (Q. phellos), and such woody shrubs as southern waxmyrtle (Myrica cerifera) and gallberry (Ilex glabra). These often occur in great profusion, with thousands of stems per acre. On the

Figure 2.--An immature loblolly pine stand, about the same age as that shown in figure 1. Fire has been excluded for 15 years. The understory is a dense, jungle-like mass of sweetgum, blackgum, and inferior oaks.

drier sites there is again sweetgum, blackgum, southern red oak and also post oak (Q. stellata), turkey oak (Q. laevis), blackjack oak (Q. marilandica), and hickories. These do not occur in such large numbers as on the moister sites, but only because the drier sites cannot support as many.

When the pine canopy is intact, the hardwood understory usually grows slowly and persists in the absence of fire. Occasional hardwoods become part of the overstory but most stay in the understory and do not grow much larger than six inches d.b.h. The occasional fire that runs through the stand will kill hardwoods up to about one or two inches d.b.h. These promptly sprout again, often in greater profusion. Loblolly pine reproduction is usually absent, or, if present, of poor form and vigor. This condition is illustrated in a stand now under observation at the Santee Experimental Forest in South Carolina. It is a well-stocked pure loblolly pine stand 50 years old on a 90-foot site, in which fire has been excluded for at least 15 years. A tally of the understory reveals over 5,000 hardwood stems per acre; about half are below breast height and the others mainly in the 0 to 1-inch class. There are also nearly 4,000 stems of woody shrubs per acre. Thus, there are about 9,000 competitors in the understory. But there are no pine seedlings, other than those that germinate during the current year.

All overstory pines in the observed stand bear cones. About every other year these trees will produce a good, if not an abundant, supply of seed. Much of the seed is intercepted by the hardwood litter and fails to germinate. Those seedlings that become established are practically all short-lived because of the heavy competition from low hardwoods and shrubs.

In stands such as this, the initial response following the removal of the overstory, either in partial or clear cuttings, is an acceleration in the growth of the understory hardwoods. However, a cutting operation usually provides a more favorable seedbed for pine, and the chances for survival are improved. Loblolly pine has a rapid growth rate, but in the initial stages of hardwood sprout development, the fast-growing first- and second-year sprouts offer serious competition to pine seedlings.

Competition is even greater when the sprouts are several years older than the pine reproduction. As a result, many cut-over areas bear vigorously growing hardwoods and only few pines. Figure 3 shows such an area. A pure stand of pine was cut to seed trees two years previously; it is apparent that the next crop will be largely inferior hardwoods.

The hardwood problem in coastal Virginia and the Carolinas is primarily one of regeneration, not one of stand improvement. If well-stocked, even-aged pine forests are desired, they must be regenerated as such. While the elimination of hardwoods in stands past the reproduction stage is commendable silviculture, it seldom increases the number of pine

Figure 3.--Before cutting to seed trees two years ago, this was a well-stocked loblolly pine stand unburned for at least 15 years. Upon release the hardwood understory grew rapidly. Pine reproduction is present but is of poor vigor and form.

stems in the stand. The point is, that after regeneration, little can be done to improve the stocking of pine.

POSSIBLE METHODS OF CONTROL

Consider what we desire in a method for controlling hardwoods. First, it must be effective. It need not eliminate or eradicate all hardwoods, but it should so restrain the vigor of competition as to permit the adequate regeneration to pine. Second, it must be economical, although we are not certain what a reasonable charge might be. And third, it must be in accord with the forest management objectives. For example, fire would not be acceptable in an all-aged forest. There are criteria other than the three mentioned, but they are relatively minor. It is unlikely that any one method will excel in all three criteria or be applicable to all conditions in all parts of the region. Moreover, it is quite probable that foresters will have to diagnose the conditions in each forest unit to be treated. Then, knowing the efficacy of the various methods, they will prescribe one, or possibly a combination of methods, that will achieve the desired results.

Methods for controlling hardwoods fall into two broad categories: (1) the non-selective, area or stand-wise treatments, and (2) the selective, individual or stem-wise treatments. Fire is an example of a non-selective treatment, being applied stand-wise with little discrimination among species or individuals. Weedings are selective treatments, where the operation is directed toward individual stems. These methods may be summarized as follows:

Method of control	Type of control	Form of management
Fire	Non-selective	Even-aged
Chemical		
a. Foliage sprays	Non-selective	Even-aged
b. Cut-surface	Selective	Even-aged and many-aged
Mechanical	Non-selective	Even-aged
Release cuttings	Selective	Even-aged and many-aged
Utilization	Selective	Even-aged and many-aged
Regulation of overstory	Non-selective	Even-aged
Grazing	Non-selective	Even-aged
Genetically improved species	Non-selective	Even-aged and many-aged

THE USE OF FIRE

Since fire has been a predominant factor in the development of the pure loblolly pine type in the coastal region, it is conceivable that fire may also serve to perpetuate the type. Foresters have become aware of the possibility of using fire as a silvicultural tool; but there seem to be two main obstacles to its general acceptance. First, we are not certain how to use it most effectively; and second, it is a pretty big instrument. We need to know the specific fire to accomplish a specific objective, and even then it is difficult to apply "a little bit of fire."

H. H. Chapman, among others, has long advocated the use of fire for the control of hardwoods and the regeneration of loblolly pine. Briefly, Professor Chapman's conclusions are (4):

For regeneration:

(1) Burn after logging, protecting the seed trees.

(2) Burning should take place in late August or September, prior to the seedfall.

(3) The fire should be as hot as can be safely managed.

(4) Repeat the fire if the area fails to regenerate.

(5) Girdle or poison hardwoods not killed by fire.

Prior to regeneration:

(1) Burn at intervals in immature stands after reproduction attains fire immunity (age 6 to 10 years).

(2) Such burning keeps the hardwoods small and manageable.

(3) Repeated fires serve to reduce wild fire hazard.

(4) Reduction of understory hardwoods may increase growth rate of the pine overstory.

Early observations in the current research program confirm many of Chapman's thoughts. Our experience with fire over the past three years emphasizes the necessity of determining conditions, selecting objectives, and using the fire which will correlate the two. This is what our current research with fire shows:

Burning for regeneration

Burning after logging.--Such fires, even though they frequently result in variable burns, have very definite advantages.

(1) Logging debris is consumed, thereby reducing physical barriers to regeneration. The amount of slash, of course, varies with the type of timber and intensity of cutting. Of two areas that were clear cut by strips, one had 17 percent and the other 31 percent of the ground surface covered by slash. Our studies show that reproduction in such logging debris is significantly less than in open areas.

(2) Logging slash adds to the fuel, makes hotter fires, and kills bigger hardwoods.

(3) Little risk to the overstory is involved if precautions are taken to protect the seed source, such as the prevention of heavy slash accumulations at the base of seed trees. This permits the use of the hottest fire consistent with fuel conditions and fire control.

(4) The time interval between hardwood reduction and pine regeneration is usually shortest if post-logging fires are used. This is particularly so if the logging of larger stands extends, as it sometimes does, over a growing season or more.

(5) Logging disturbance, interior roads and skid trails form fire breaks that increase the costs of burning. Two very satisfactory post-logging fires were made during 1948 in one locality but similar fires in another place effectively burned less than half the designated area--even with intensive and costly interior spot burning.

Burning prior to logging.--We have found that pre-logging fires also have merit. Although they do not solve the slash disposal problem, they are usually cheaper and produce more uniform burns. Furthermore, they make marking, felling, and bucking easier, and fewer logs get lost in the brush. Fire mortality losses are negligible if harvesting closely follows the fire. If the fire is timed prior to the seed fall and logging occurs after the seed fall (late December or January), the seed bed is prepared to receive the seed from the entire uncut stand rather than from scattered trees. Harvesting should closely follow pre-logging fires, otherwise the resprouting hardwoods again become competitors. If possible, not more than two or three months of the growing season should elapse between burning and logging.

Season of burning.--Professor Chapman's recommendations for burning in late August or September are well taken because:

(1) It anticipates the seed fall, which usually peaks during the first part of November.

(2) Summer fires tend to be hot fires and kill hardwood stems up to three or four inches d.b.h. On the other hand, the average winter fire kills hardwoods up to one to two inches d.b.h.

(3) There is evidence that fires at some period during the growing season may reduce the number and vigor of sprouts of some species.

(4) Sprouts following late growing-season fires have little opportunity to grow prior to the dormant season. This puts the pine and hardwood on almost equal footing the following spring.

However, it may be difficult to do. In the late summer of 1946 and again in 1947, it was impossible to burn large areas in the Carolinas because of wet conditions. In any case, the number of burning days is definitely limited. Near drought conditions are often required for much fuel is green or in the early transition stage. The difficulties in making satisfactory large-scale burns are further magnified when growing-season fires are made after logging. Recognizing the advantages of late growing-season fires but also recognizing the possibility of not being able to burn at all, the alternatives are (1) to burn during the first opportune period, beginning

with the mid-growing season; or (2) to burn early in the winter, for there is evidence that at least some seed are dispersed throughout the entire dormant season.

Type of fire.--A hot fire is needed for the reduction of hardwoods at the time of regeneration. As pointed out by Lindenmuth and Byram (7), backfires are hotter near the ground than headfires. Not only are backfires hotter but the duration of heat is longer at the base of the stems. Backfires, therefore, are generally preferred for the reduction of hardwoods. However, there are conditions under which headfires may be necessary. In certain types of fuels, such as thin hardwood litter or flat fuels, backfires may spread too slowly and be too costly to apply.

Burning in immature stands

The stems of the hardwood understory in dense young pine stands (less than 10 to 20 years) are normally small and slow growing. As the stands become older and more open, through either natural or artificial thinning, the hardwoods grow larger. They become more difficult to control. One way to keep hardwoods small and controllable is to make periodic burns. If the burning schedule is begun early enough, the stands may eventually be regenerated with only a single burn at the time of harvesting. Girdling or poisoning may be unnecessary.

Season of burning.--In general, dormant-season fires are more efficient in immature stands. The advantages that growing-season fires have for regeneration are unimportant in immature stands because:

(1) Anticipation of seed fall is unnecessary.

(2) Reduced vigor of sprouting is not essential.

(3) Very hot fires are hazardous to the immature overstory.

Frequency of fires.--While frequent light fires are more satisfactory than infrequent hot fires, annual burns are unnecessary. Since the average winter fire kills hardwoods up to one to two inches d.b.h., it is unnecessary to burn at intervals more frequent than the time required to grow to that size. Depending upon density of the overstory, site, and species, it takes from 5 to 15 years for understory hardwoods to reach the maximum controllable size.

Costs of burning

Costs of prescribed burning vary so much by size and shape of area, fuel conditions, and crew organization and training that present average costs are not very useful. Prescribed burning has been done on a large scale by the National Forests for as little as 10 to 15 cents per acre. Elsewhere it has cost as much as $3.00 per acre. Eventually we may isolate the cost effect of specific variables and determine the cheapest and most effective fire for given conditions.

The effect of fire on site

We do not know whether or not pine sites will deteriorate after repeated burning. Brief studies of the effect of fire on the chemical quality of the soil, the physical characteristics, biological activity, and water relationships indicate that we need not be unduly alarmed about prescribed burning in the flatwoods region. After reviewing the literature, G. L. Hayes, formerly of the Southeastern Forest Experiment Station, concluded that:

(1) Frequent burning causes no vital loss of plant nutrients from the soil.

(2) Fire changes the physical soil characteristics. The soil becomes more compact and less absorptive to water. While this increases water run-off and soil erosion in many parts of the country, it is evidently not serious in the flatwoods.

(3) Micro-organisms in the litter are destroyed by fire but benefit from fire in the soil itself. The net effect of fire on micro-organisms may be beneficial in the pine region, since little incorporation of surface litter into the soil takes place in any case.

These conclusions may change after further study; nevertheless, it is very reassuring that the pine site index in the coastal region is high even after many generations of repeated and uncontrolled fires. Prescribed burning in immature stands need only be light winter fires at intervals of perhaps ten years or so. These fires seldom consume more than the surface litter.

Suggested use of fire

To summarize, the place of fire in the regeneration of loblolly pine is two-fold: First, it serves to prepare the seedbed by consuming surface litter and logging debris. Second, under certain conditions, it reduces the competitive vigor of hardwoods. Keeping in mind the objective of using fire in such a way as to encourage maximum pine germination and survival, and to discourage hardwood competition, we can suggest its use as follows:

(1) Use winter fires in immature pine stands at intervals to keep hardwoods small and controllable; that is, below one to two inches d.b.h. Where understory hardwoods are larger than about two inches d.b.h., it is too late to use fire alone as a control measure.

(2) For regeneration of mature pine stands where the hardwoods are below one to two inches d.b.h., a fire prior to the seedfall, before winter logging or subsequent to summer logging, will serve to prepare the seedbed and reduce hardwood competition. Large hardwoods will have to be reduced by means other than fire.

(3) In areas failing to regenerate to pine, fires in late summer prior to a good seed year will prepare the seedbed and control small hardwoods.

But fire is no universal remedy. In addition to the limitation of the size of hardwoods that can be controlled by fire, there are a number of practical difficulties. Fire is permissible only when even-aged stands are desired either as extensive areas or in small groups. Fuel conditions in some stands may be such as to produce ineffective burns. Weather conditions frequently do not permit the use of fire when desired, so that compromises must be made between the objective and the practice. There are also the complexities involved in weaning the public away from the hard-won concept of fire exclusion. Furthermore, it is possible that the cure may be worse than the disease, for we have very little knowledge of the long range effects of fire on the site. Despite these limitations, fire very definitely has a useful place in the regeneration of loblolly pine.

THE USE OF CHEMICALS

During the past few years intense interest has been aroused in the use of chemicals to control undesirable vegetation. While most of the investigations have been directed toward the control of weeds in agricultural crops, foresters and others have been alert to the possibilities of control of woody species. As a matter of fact, the poisoning of trees has been practiced for many years, but the recently developed herbicides and silvicides have opened new possibilities.

There are dozens of chemicals that are toxic to woody plants. All have their peculiar properties; some may be useful, others objectionable. In addition to conforming to the three criteria requisite to a control method--effectiveness, economy, and adaptability--the following attributes are desirable in a silvicide:

(1) Not only should it destroy aerial portions but it should also reduce or eliminate subsequent sprouting. Otherwise it would have no advantage over fire or cutting.

(2) It should be safe to handle and nontoxic to livestock and wildlife.

(3) A silvicide would be exceedingly useful if it were completely selective; that is, toxic to undesirable species and nontoxic to desirable species. However, lacking complete selectivity it should have no selectivity, so that a single chemical could be used for all species.

(4) Properties of the chemical should be such that if any is spilled soil sterilization will only be temporary.

When chemicals are used as foliage sprays, there is little or no discrimination except where certain species or stem sizes are not susceptible to the toxicity of the chemical. Since pine as well as many hardwoods are susceptible, foliage sprays can be used only with even-aged management. Chemicals can also be applied to cut surfaces either in dry form or in solution on stumps or ax cuts in the stem. Since the operator may choose which stems to treat, such selective treatment is adaptable to both even-aged and many-aged management systems.

Current investigations in the use of silvicides testing various

chemicals, concentrations, and application techniques have given us preliminary information which might aid us in evaluating their efficiency in controlling hardwoods. The three chemicals that show the most promise are 2,4-D (2,4-Dichlorophenoxyacetic acid), 2,4,5-T (2,4,5-Trichlorophenoxyacetic acid), and "Ammate" (ammonium sulfamate).

Non-selective, stand-wise control with silvicides.--When the understory is composed of many small hardwood stems, as it frequently is, the treatment of individuals is quite costly. Although stand-wise treatment with fire is relatively cheap, a single burn seldom reduces the number and vigor of hardwood sprouts. It merely reduces their size. Even though a fire at the time of regeneration favors pine, hardwoods are so aggressive that many will become dominant in the succeeding stand. Thus it may be advantageous to supplement the effect of fire by reducing the number of hardwood competitors by chemical means.

With aqueous solutions of the ammonium salt of 2,4-D applied as foliage sprays, we have found that:

(1) 2,4-D will kill many hardwood root stocks, as shown in figure 4.

(2) Foliage sprays must be applied to sprouts less than about four feet in height. Foliage sprays cannot be used effectively unless larger hardwood stems are first reduced by fire or other means.

(3) Concentrations of about 0.5 percent of the acid (by weight) are needed.

(4) Complete foliage coverage is required to kill individual trees.

(5) Dosage depends upon the hardwood population. From 50 to 100 gallons of solution per acre are required to completely treat fairly dense one-year-old sprout stands.

(6) The most effective spraying season is about the time of formation of terminal buds of first-year sprouts (early August). It appears that second-year sprouts may be treated any time after full leafing in the spring.

(7) Species susceptibility varies. Sweetgum is harder to kill than blackgum or most oaks. Large and vigorous root stocks are more difficult to destroy than smaller roots. So, depending upon species and root conditions, there are varying degrees of residual sprouting following treatment with 2,4-D.

Figure 4.--Effect of 2,4-D treatment in an immature stand. The understory prior to treatment was similar to that shown in figure 2. The area was treated with a summer fire in June 1946, and the resultant sprouts were treated with a 2,4-D foliage spray in late August 1946. Photo taken in September 1948.

The ammonium salt of 2,4-D is no longer manufactured. It has been replaced by the sodium salt, which appears to be of equal cost and effectiveness. Generally the salts of 2,4-D are less toxic to woody species than the esters. However, they are also less costly. We do not know whether the greater effectiveness of the esters is worth the additional cost. They do have better foliage adhesion and faster penetration. This permits the use of the esters pretty much without regard to weather, while the salts of 2,4-D may be washed from the foliage by rains occurring within six hours following application. Perhaps this advantage alone is worth the extra cost.

The chemical cost of foliage sprays is high.

Silvicide	Chemical cost per acre, using 0.5% concentration of 2,4-D acid at the rate of 60 gallons per acre
Sodium salt of 2,4-D	$2.95
Isopropyl ester of 2,4-D	5.58
Isopropyl ester of 2,4, 5-T	5.80

For comparison, the cost of ammate sprays at the recommended concentration of 32.5% (4 lbs. per gallon of water) at the rate of 60 gallons per acre is about $30.00.

We have little information on labor and equipment costs, but it is likely that application costs will be at least as high as that of the chemicals. To kill 50 percent or more of the hardwood root stocks in dense sprout stands costs about $6.00 per acre with the salts of 2,4-D.

Selective, stem-wise control with silvicides.--When relatively few or large hardwoods are present, excellent control can be obtained with ammate, either as crystals in chopped cups or in solution in ax-cut frills. Peevy[2/] of the Southern Forest Experiment Station recommends ammate crystals in cups, as follows: "Dry crystals of ammonium sulfamate are placed directly into the trees in a simple cup or notch chopped in the main trunk or main roots at ground level......Cups are made 6 inches apart around the base of the tree and 1/2 ounce of crystals is placed in each cup." Time studies (9) show that the treatment costs about $3\frac{1}{2}$ cents per tree for trees averaging eight inches d.b.h., charging 75 cents per hour for labor and $13\frac{1}{2}$ cents per pound of ammate. Thus, about 100 trees per acre averaging eight inches d.b.h. can be treated for $3.50.

Investigations with ammate in South Carolina have been limited to seasonal tests with certain species. We have found that better results are obtained with a dosage of one ounce per cup. This raises the cost per 8-inch tree by $1\frac{1}{2}$ cents. However, with that dosage about 1,000 trees were treated

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2/ Peevy, Fred A. How to kill blackjack oaks with ammate. Southern Forest Experiment Station. Mimeographed 3 pp. Oct. 3, 1947 (revised).

(sweetgum, blackgum, and water, willow and post oaks), and every tree was killed regardless of season of application. Resprouting was insignificant after one year. The cost of control with ammate can be somewhat reduced in stands of conspicuous sprout clumps, because sweetgum sprouts in clumps--from parent stumps and by root suckers. With practice it is not difficult to recognize stems having common root systems, and then treatment of the largest stem in a clump with a double dose of ammate effectively controls the smaller stems. We have had no success in similar treatments with 2,4-D foliage sprays.

There is a possibility of effecting stem-wise control with 2,4-D in stands where there are many hardwoods below the sizes economical to treat with ammate crystals. The stems may be cut with brush hooks, mechanical saws, or other means and the stumps sprayed or painted with oil solutions of 2,4-D or 2,4,5-T in high concentrations. This may be done during the dormant season as well as during the growing season.

Suggested use of silvicides

While it is certain that the control of hardwoods can be obtained more effectively by the use of silvicides than by the use of fire alone, we do not yet know whether such additional control is essential or practical. If such control is desired, we suggest the following practices, although continuing research may soon alter these suggestions:

(1) For hardwood reduction in immature pine stands, keep the hardwoods below two inches d.b.h. by winter fires. Several years prior to the harvest cut, make a final winter fire and follow with a foliage spray of the sprouts during the next summer. A seed bed preparation fire can be made at the time of regeneration. The foliage spray should be aqueous solutions of about 0.5 percent concentration of the acid (by weight) of either the sodium salt of 2,4-D or one of the esters of 2,4-D or 2,4,5-T.

(2) If the hardwoods are larger than the size that can be reduced by fire, no silvicide treatment is recommended prior to the regeneration cut.

(3) Because of practical difficulties, foliage sprays on a large scale are not recommended immediately following a regeneration cut. If,

several years following the cutting, the area has not regenerated to pine and the hardwoods are of small size, a treatment of fire or mechanical scarification followed by foliage sprays can be used.

(4) Following the regeneration cut, large hardwoods can be controlled by cut-surface treatments with ammate or highly concentrated oil solutions of 2,4-D or 2,4,5-T.

(5) If fire is not desired at any point in the management program, effective control of hardwoods can be obtained with cut-surface treatments, although at a higher cost than with foliage sprays.

THE USE OF MECHANICAL METHODS

The control of hardwoods by mechanical methods may offer decided possibilities. In effect control has been accomplished in the past through cultivation, with the consequent establishment of pure pine on abandoned fields. For forest use, mechanical treatments may range from simple tractor logging to mechanical brush cutting, brush busting, bulldozing, or disking. The control of hardwoods by such methods seems to be quite effective, although temporarily so, for unless the trees are completely uprooted, sprouting usually follows. However, these methods offer the very definite advantage of seedbed improvement by soil scarification. Although this Station has done little work in mechanical control, other organizations have made large scale tests. It is too early to assess the results but it may be useful to summarize briefly the techniques employed. Observations made by K. B. Pomeroy, of the Southeastern Forest Experiment Station, on lumber and pulp company lands near Franklin, Va., are as follows:

Bulldozing.--One industrial organization uses HD-19 and D-7 bulldozers on lands that fail to regenerate to loblolly pine. Under average conditions the bulldozer blade is raised just high enough to clear the ground. Two large stumps are dragged behind the tractor. As the equipment lumbers along, covering 1/2 to 3/4 acres per hour, brush, shrubs and trees up to five or six inches d.b.h. are uprooted and left wherever they come to rest. This procedure exposes mineral soil over much of the ground. In dense stands of hardwoods the stump drag is disconnected and the activity

becomes a land clearing job. Under this condition the debris is left in windrows about 100 feet apart, or pushed into depressions that are not good pine sites. After salvaging merchantable trees and crediting this amount to the operation, the net cost, according to the Company, is less than $10.00 per acre.

Pomeroy[3/] has shown that establishment of loblolly pine seedlings on soil surfaces compacted by heavy equipment and subsequently "puddled" is greatly inferior to that on other areas less severely disturbed. Subsequent height growth of seedlings on compacted areas, at least for the first two years, is less than half that of seedlings on other surfaces. Only time will tell whether the use of heavy bulldozers to remove hardwoods, especially on the heavier soils, will significantly damage the site.

Scarification.--Another organization has used a disk with stump drag attached to treat areas immediately before harvest cutting. This disturbance plus that normally associated with tractor skidding exposes mineral soil on nearly all the ground surface not covered by slash piles. Production varies from 1 to $1\frac{1}{4}$ acres per tractor hour.

A third company experimentally used two tree tops dragged behind a tractor on areas previously logged. Satisfactory scarification is accomplished at the rate of 0.63 acres per tractor hour. A more thorough job of scarification has been done by substituting a heavy farm disk for the tree tops, pulled by a D-2 tractor.

Mechanical brush cutting.--The South Carolina State Commission of Forestry has treated scrub-oak areas in the Sandhills with Marden Brush Cutters followed by a disk. Complete exposure of the mineral soil has been obtained at the rate of about one acre per equipment hour. However, small bits of scrub oak root stocks left in the ground sprout vigorously. The Station is treating these sprouts with foliage sprays of 2,4-D.

3/ Pomeroy, K. B. The germination and initial establishment of loblolly pine under various surface soil conditions. Manuscript submitted to Journal of Forestry, 1949.

Suggested use of mechanical methods

Mechanical methods are most useful when fire is either not desired or cannot be used effectively because of unfavorable burning conditions or because the hardwoods are too large to be killed by fire. Since soil scarification is of considerable value, mechanical treatment can be used in combination with silvicides to effect intensive control of hardwoods.

Obviously these methods are not applicable to immature pine stands. They can be used immediately prior to or after logging for regeneration, or in the reconversion of recent hardwood invaded lands back to pine. If used prior to harvesting, these methods may increase logging costs by excessively disturbing the ground surface. On the other hand, if used after logging, the presence of slash may increase operating costs.

THE USE OF RELEASE CUTTINGS

The most direct method of controlling species composition has always been with the ax; at the source. This is frequently done in the form of weeding or cleanings, liberation, and improvement cuttings. But whatever the operation is called, the intent is the same: Here is a desirable tree being crowded by less desirable neighbors; destroy the neighbors! Such treatment is selective, individual, and stem-wise in the strictest sense.

Release cuttings have considerable merit, for: (1) they are likely to be effective, (2) costs could be reasonable (or not, depending upon the population of neighbors), and (3) they are well adapted to all forms of management. Inasmuch as release cuttings are recognized cultural methods--although much more must be learned of specific techniques--it seems reasonable they should be used as standards by which all other methods are evaluated.

The two methods generally employed in the release of desirable reproduction are girdling and weeding. Overhead competition by non-merchantable or undesirable individuals can readily be removed by girdling. The cost varies with number and size of trees treated. Several large-scale girdling operations report a cost of about $2.00 per acre. Fragmentary records indicate

that the cost of girdling is about the same as the cost of using ammate in cups or frills. Girdling is an effective method for relatively few and large stems, but our problem areas frequently have so many hardwoods that girdling becomes virtually a hopeless task.

Because of the relative ease in the past of obtaining pine reproduction in the flatwoods, little consideration had ever been given to weedings as cultural measures. They were seldom needed then, but as the hardwood invasion spreads, they become more important. A few studies have recently been started to determine the efficiency of methods and costs; however, it is still too early to assess results. Information is needed on all phases: when release is needed, what soils and sites are most favorable, what type of seedling to release, how much release is needed, when is the best season of treatment, and which are the most effective methods and equipment.

A number of weeding trials have failed because of the resprouting of the cut stems. This has necessitated a second and later release. An interesting possibility is offered--that of chemical weeding. By applying ammate or oil solutions of 2,4-D or 2,4,5-T to the cut surfaces, there may be no need of further treatment. This procedure is being investigated.

One must consider that if very heavy weedings are required, it is probable that the area is poorly stocked with pine. It might be more efficient to reduce the hardwoods (and the pine) by such area treatments as fire, chemicals, or mechanical methods, and encourage reseeding to more densely stocked reproduction.

Suggested use of release cuttings

Release cuttings are best adapted to the many-aged management system where area treatments cannot be used. They can also be effectively used in the even-aged system where pine reproduction is already established in satisfactory numbers but where release from competition is needed. The decision must be made whether to release the existing pine or to destroy it by area treatments and gamble on satisfactory restocking.

OTHER METHODS OF CONTROL

If markets were regionally available for hardwoods of all species, form, and size, there would be no hardwood problem. Unfortunately they are not. However, uses have been developed for heretofore worthless species, markets have been expanded, and perhaps more can be done. Where utilization opportunities are available, they should easily fit in with any additional effort required for the control of hardwoods.

In areas where hardwood competition is not too severe at the moment, it might be possible to keep hardwoods in check by maintaining closed canopies. This method is only a temporary one, for we can expect increased competition with each successive regeneration period. It permits little or no thinning and may best succeed with even-aged short rotations.

There may be other ways to perpetuate pine. Perhaps by grazing we can control hardwoods and at the same time produce a supplementary crop. Perhaps we can develop superior strains of pine trees with greater tolerance or very rapid initial growth. Such genetic development is vaguely remote, but its possibilities should not be ignored.

With regard to the methods of control described in this Note we must again caution against the acceptance of any one treatment for use under all conditions in all parts of the region. Furthermore, these treatments require a high degree of skill in application. Used carelessly or unskillfully, such tools as fire and silvicides may create many more problems than they solve.

The suggested treatments are, of course, preliminary and tentative. In addition, they are presumed to be applicable to "ideal" conditions, so that modifications will frequently be necessary.

SUMMARY OF SUGGESTED TREATMENTS

EVEN-AGED MANAGEMENT

Forest condition	Fire		Chemicals		Mechanical methods		Release cuttings
IMMATURE PINE STANDS							
(1) Most hardwoods below 1 to 2 inches d.b.h.	Periodic winter fires		None		None		None
(2) Most hardwoods above 1 to 2 inches d.b.h.	None		None		None		None
MATURE PINE STANDS							
(1) Most hardwoods below 1 to 2 inches d.b.h.	Burn prior to seedfall,[1] before winter logging or after summer logging	OR	Foliage sprays following fire, a few years before logging	OR	Disk before logging		None
(2) Most hardwoods above 1 to 2 inches d.b.h.	Burn prior to seedfall,[1] before logging	AND	Cut-surface treatments after logging	OR	Bulldoze or disk prior to seedfall		None
REGENERATION AREAS							
(1) Few pines, few hardwoods	Burn prior to seedfall in good seed year[1]		None	OR	Scarify in good seed year		None
(2) Few pines, many hardwoods	Burn prior to seedfall in good seed year[1]	OR	Foliage sprays (after fire or disking) or cut-surface treatments	OR	Bulldoze or disk prior to seedfall in good seed year		None
(3) Adequate pine, many hardwoods	None		Cut-surface treatments		None	OR	Weed and girdle

MANY-AGED MANAGEMENT

ALL STANDS	None		Cut-surface Treatments		None	OR	Weed and girdle

1/ Fuel and weather conditions may not permit burning in late September or early October, just prior to seedfall. The alternative is to burn at the first opportune time between mid-July and mid-December.

FUTURE WORK

Our research in methods of controlling hardwoods will continue along present lines, expanding in those directions that appear rewarding and contracting where indicated. We believe that if we knew more about the behavior of hardwoods, and pine too, we would be better equipped to investigate control methods. Some gaps in present knowledge are: How fast do hardwoods grow? How do they sprout? What resistance does pine have to competition by various species and on different sites? Behavior studies must be pursued as vigorously as those of control.

At the same time we believe it extremely urgent to initiate soil and site studies. Three related fields of investigation are indicated:

(1) Degradation of site by continuous cropping of pine. We must determine whether successive stands of pure pine will reduce soil fertility. There is evidence that this is true in other regions. Will our flatwoods soils behave similarly?

(2) Effect of control methods on soils. Apart from the reduction of hardwoods and hardwood litter, what site changes might be expected from repeated fires that burn the humus and may alter soil structure? From chemicals that may contaminate the soil? From bulldozers that puddle and compact a portion of the treated area?

(3) Classification of sites to determine where present conversion to hardwoods may be more favorable than retention in pine. We would like to be able to say: Here is a pine area which, properly managed, will grow excellent hardwoods; the difficulties in maintaining pine are great, so let it revert to hardwood. It is expected that any classification of site must be a flexible one, for even the relative yields of pine and hardwood may not be constant for given soils because of improvement in management technique. Relative values change with market conditions. Add to this the changes in cost of control and we have a rather complicated structure.

When these soil and site studies have been made, we'll be in a better position to tell the timber grower what to do, where to do it, and how much it will cost.

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